Erosion Testing of Coatings for V-22 Aircraft Applications

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V-22 Osprey

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Background:

- Rotary-wing and VSTOL fixed wing aircraft are suceptible to sand erosion particularly during takeoff and landing.

- particularly susceptible are helicopter rotors and engine air intakes, e.g. compressor airfoils and impellers, where the high rpm of the components creates a high relative velocity, e.g. 1000-2000 ft/sec, between the erodent and the device.

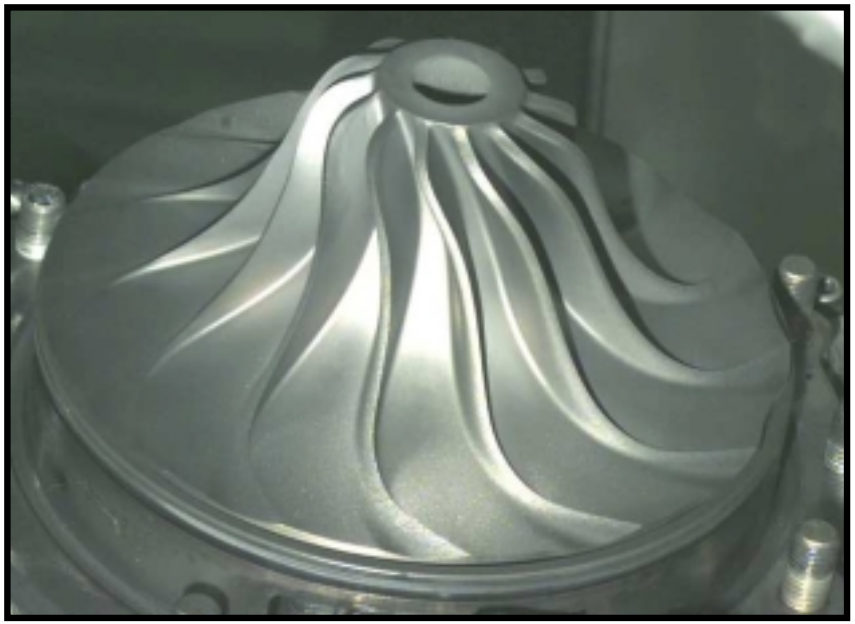
- The Navy's V-22 (Osprey) tilt-rotor aircraft has a sand erosion problem with the Titanium impeller on its Shaft Driven Compressor (SDC) limiting its life to less than 300 hours.

- The SDC provides compressed air for : heating & a/c, oxygen generation, fuel tank inerting and wing de-ice boots.

V-22 SDC Impeller

Impeller from Axial Compressor

New



Worn

Navy SBIR Topic: N00-002
TPOC: Dr. George Y. Richardson

TITLE: Compressor Impeller Erosion Resistant Surface Treatment

OBJECTIVE: The primary objective of the work is to develop an innovative surface treatment for shaft driven compressor (SDC) impellers in aircraft applications which prevents erosion of the impeller.

Stakeholder: PMA-275, V-22

V-22 Osprey

Contract Award Recipients (3)
Phase I - $70k each

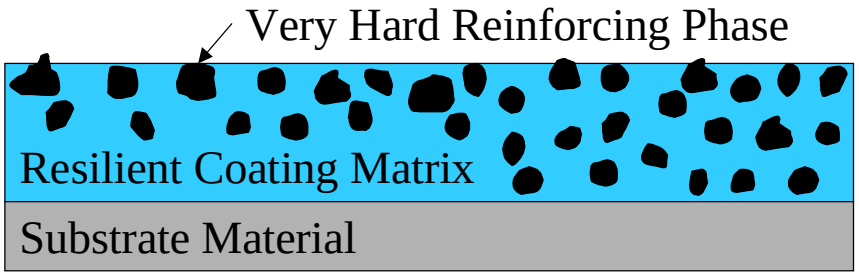
- Analytical Services & Materials, Inc. (AS&M)
  Hampton, VA
  - Ceramic particles in a polymer matrix

- Surface Treatment Technologies, Inc. (STT)
  Tullahoma, TN
  - Electro Spark Deposition of WC/TaC/TiC

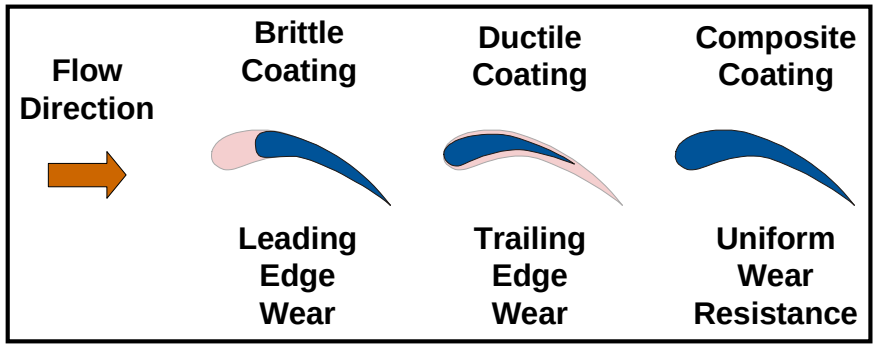
- SURMET, Corp.
  Burlington, MA
  - CVD of Si_xC_y/DLC

AS&M Process Description

Composite Coating Concept



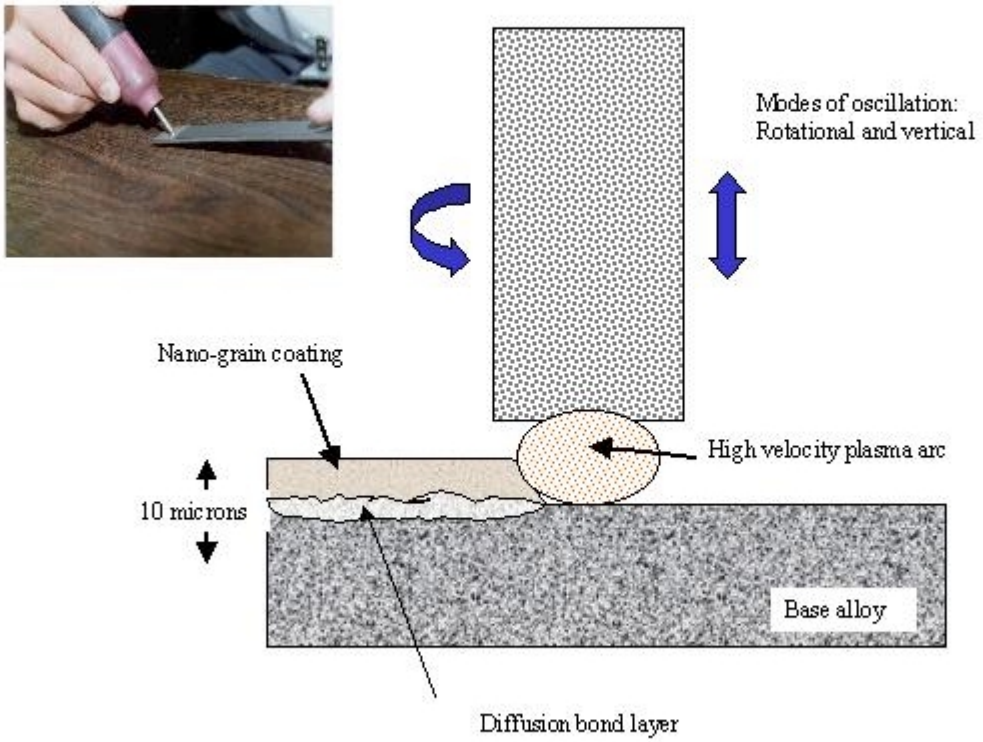
Benefit



Hard, brittle coatings tend to do poorly at high impingement angles but well at low impingement angles. Ductile coatings, because they can better absorb the energy of impact, do well at high impingement angles but, because they are soft, do poorly at low impingement angles. Consequently, hard, brittle coatings experience leading edge wear and soft, ductile coatings experience trailing edge wear. AS&M's concept of a composite coating provides good energy absorption at high impingement angles and good abrasion resistance at low angles leading to improved and uniform erosion resistance.

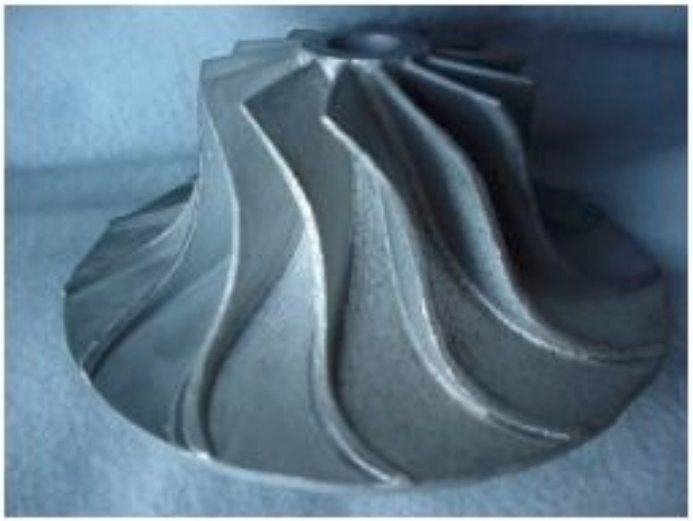
STT Process Description

V-22 Impeller Erosion: ESA Approach



Electro Spark Deposition of WC-TaC-Co and WC-TiC-Co

V-22 Impeller Erosion: Hardware Application



- demo part coated using hand applied ESA
- ultimate application readily automated
- surface texture possible issue – can be modified

SURMET Process Description

Coatings of Si_xC_y and DLC are deposited by Low Temp (<150 C) Plasma Assisted CVD

- DLC coatings alone
- SiC/DLC bi-layer
- multilayered coatings (25 layers): enhance toughness and wear resistance, surface compressive stress for fatigue resistance.

Coated Impeller(s)

Process Characteristics

- AS&M (polymer/ceramic composite)
  - low temp and low cost, can be applied by conventional methods, e.g. spraying and dipping.

- STT (Electro Spark Deposition/Alloying)
  - localized high temperature process, metallurgical bond between coating and substrate, rough surface, high density (heavy) coating, e.g. (W,Ti,Ta)C/ Co.

- SURMET (CVD)
  - low Temp process (<150 C), conformal coating process, uniform coating, vacuum deposition.

Erosion Testing @ University Of Cincinatti

- Testing conducted on 1 in^2 coupons in a wind tunnel facility
- Two types of erodent media (separately)
  - 9.5 µm Alumina
  - 100 - 200 µm SiO_2 (Arizona Dust)
- Velocity of Air Stream/particles = 600 ft/sec.
- Particle Loading, 5-100g/10 minute exposures.
- Incident Angles - 30, 90 degrees

Erosion Test Results
(Univ. of Cincinatti)

Company	Sample	Erodent, Angle, Mass	Erosion Rate (w/g)	Remarks
Surface Treatment Tech., Inc	7473(12)	9.5 µm Al_2O_3,30°, 5g	1.206	Uncoated Baseline-Ti
"		SiO_2 Arizona Dust, 90°, 10g	2.3	"
"		100-200 µm, SiO_2, 90°, 100g	1.8	"
"	7422 (1)	9.5 µm Al_2O_3 , 90°, 5g	0.16	Coated-WC-TiC-Co
"	7422 (7)	9.5 µm Al_2O_3 , 30°, 5g	0.49	Coated- WC-TiC-Co
SURMET	5	9.5 µm Al_2O_3 , 90°, 5g	0.092	DLC/SiC multilayer
"		9.5 µm Al_2O_3 , 30°, 5g	0.6	DLC
AS&M	KRET 134 (8)	9.5 µm Al_2O_3 , 30°, 10g	0.045	Polymer, 37 w/o Si_3N_4
"	"	100-200 µm, SiO_2, 90°, 100g	0.054	"
"	KRET 231	9.5 µm Al_2O_3 , 90°, 20 g	0.154	Sol Gel, 16 % Si_3N_4
	KRET 249			TiC filler w/ Hi T (siloxane) polymer

Summary

• Coated impellers have shown an order of magnitude (10x) improvement in erosion resistance over baseline Ti.

• AS&M has been recommended to the program office for Phase II SBIR funding ($750K).

• Coatings program provides risk reduction to planned Ceramic Impeller program (with Honeywell Ceramics) and may potentially have fewer hurdles to implementation thereby providing a more near-term remedy.

• Component level erosion tests of coated impellers in an actual compressor are planned for Phase II.